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AN NTC LIVE FIRE PERFORMANCE ANALYSIS

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The BDM Corporation

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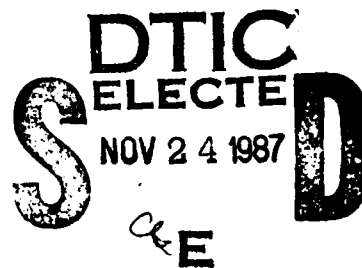


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AN NTC LIVE-FIRE PERFORMANCE ANALYSIS

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AN NTC LIVE FIRE PERFORMANCE ANALYSIS

EXECUTIVE SUMMARY

The training benefits derived by units training at the National Training Center (NTC) have been of considerable interest to the U.S. Army. The Army Research Institute (ARI) has developed and initiated a programmatic research effort to assess these benefits. As a preliminary step in this effort, an exploratory data analysis of the performances of battalion task forces on the live-fire range at the NTC was conducted. As stated by Tukey (1977) the purpose of exploratory data analysis is to be detective in nature not confirmatory. Thus, the investigation reflects incursions into the data designed to explicate the structure of the data rather than to confirm a particular model of the data. Using the data provided in 54 Take Home Packages for the period of early 1982 to late 1984, it was possible to examine battalion performance for three live-fire scenarios: Defend from a Battle Position (Day), Defend from a Battle Position (Night), and Movement to Contact (Day). The presentation of these data was organized around three primary issues:

- (1) Has battalion performance changed over time at the NTC?
- (2) How do the performances of the Armor and Mechanized Infantry Task Forces differ?
- (3) What factors seem to be related to performance at the NTC?

Using the "percentage of target kills" data as an indicator of meaningful unit performance on the live-fire range at the NTC and comparing the battalion performances in the first 18 months with those of the next 12 months of a 2-1/2 year period (early 1982 to late 1984), this study found that:

(1) The percent of targets killed by the tanks of the Armor and Mechanized Infantry Task Forces increased between the first and second periods of this study.

(2) The increase in percent of targets killed between the first and second periods was attributable to both one-time visitors to the NTC and to repeat visitors to the NTC. Therefore, the differences in performance was a function of some phenomena associated with time and not just some advantage factor acquired through repeat visits to the NTC as might be expected.

(3) The change in performances on the live-fire ranges was probably not a function of the activities involved in the operation of the live-fire range by NTC cadre; i.e., the live-fire exercises were conducted in a uniformly consistent manner throughout the 2-1/2 year period of this study.

(4) The change in percent of target-kills over time was not related to gunnery accuracy as this did not change over time. However, a significant increase in the volume of tank rounds fired

by both the Armor and Mechanized Infantry Task Forces in the second period was likely related to the observed increase in target kills.

(5) The increase in rounds fired was related to an increase in number of tanks assigned to the task forces (particularly to the mechanized units) in the second period and to an increase in the number of rounds fired per tank.

(6) A positive and statistically significant relationship was found between the number of rounds fired per tank and the percent of enemy killed. This relationship was strongest for the day attack and day defend missions.

INTRODUCTION

The training benefits derived from units training at the National Training Center (NTC), Fort Irwin, California, have been a subject of great interest to the U.S. Army ever since the activation of the NTC in 1981. The Army Research Institute (ARI) has developed a research program which includes the assessment of these benefits as one of the key research technical objectives. Critical to the accomplishment of this technical objective is the analysis of the performance data of battalion task forces which have trained at the Fort Irwin facility. As an initial step in this research effort, an exploratory data analysis of the performances of the units which trained on the live-fire range at the NTC was conducted. It is important at this point to clarify the nature of exploratory data analysis, particularly as it relates to confirmatory analysis, as used in this study.

Exploratory data analysis has emerged as a separate, legitimate form of data analysis in the social sciences within the past ten years. This has resulted from the work of the statistician, John Tukey, who created many of the specific techniques now applied within this framework. Tukey (1977) describes exploratory data analysis as being detective in character, while confirmatory data analysis is judicial or quasi-judicial in character. Exploratory data analysis can never be the whole story but nothing else can serve as the foundation stone -- as the first step. Thus, the nature and purpose of exploratory data analysis is to provide a description or picture of the data, with the approach taken to explicate a set of data necessarily being idiosyncratic to the situation. This approach has been succinctly summarized by Hartwig and Dearing (1979): "Exploratory data analysis is interactive and iterative. There is no invariant procedure by which the exploratory data analyst takes a data set and automatically generates the smooth and the rough. Indeed, different exploratory analysts may legitimately apply different techniques and even find different structures in the same set of data." It is clear from this statement that an exploratory data analysis is in fact a series of analyses the results of which fuel other excursions into the data and hence further analyses. A three step course is generally recommended (Hartwig and Dearing, 1979) in proceeding with an exploratory analysis: (1) Understand each variable as a separate entity. (2) Understand pairs of variables and relationships. (3) Understand groups of variables as models. The limitations of space and time have restricted the present study to the first two of these steps.

To facilitate presentation, the analytic results have been organized around three general issues:

(1) Has battalion live-fire performance changed over time at the NTC?

(2) How do the live-fire performances of the Armor and Mechanized Infantry Task Forces differ?

(3) What factors seem to be related to live-fire performance at the NTC?

The results relevant to these questions provide the basis for preliminary insights into the benefits gained and the factors influencing gain at the NTC.

The remainder of this report has been organized into four sections. The initial section (Background) provides a brief description of the Live-Fire exercises at the NTC. The second section (Procedure) presents the details of the technical approach to the above issues. The third section (Results) presents the findings of the analysis used to address the study issues. A short conclusion section follows the presentation of the results.

BACKGROUND

Each battalion task force in this study performed three missions on the live-fire range. These missions were:

- Defend from a Battle Position (day)
- Defend from a Battle Position (night)
- Movement to Contact (day)

The live-fire defense training area consists of terrain, targets, and control mechanisms which present an attack by two enemy battalions against the defending task force. A diagram of the live-fire defense facility is in Figure 1. Live-fire cadre operate the training facility from the control bunker. The target scenario is computer driven. Cadre members control the target array to adjust for unit positioning and for the employment of obstacles. The live-fire cadre coordinate range activities with the observer controllers who accompany the unit and the Tactical Operations Center (TOC) personnel who provide the command and control functions over the battalion task force player unit.

The live-fire team also prepares and operates the live-fire offense facility. A diagram of the offense training area is shown in Figure 2. The live-fire controllers move with the task force in the offense and activate the enemy targets by the use of radio signal transmitters. The senior observer controller coordinates the presentation of targets to achieve unit tactical training objectives.

For each brigade rotation, one battalion task force performs on the live-fire range during the middle of its rotation while the other battalion task force from the brigade undergoes the live-fire training at the end of its rotation. It should be noted that the typical Brigade rotation includes one Armor Task Force and one Mechanized Infantry Task Force. A sample 14-day rotation schedule for each brigade rotational cycle appears below:

MISSIONS CONDUCTED	
TF_____ conducted the following missions during their NTC training period:	
DATE	MISSION
	Deliberate Attack
	Defend in Sector
	Defend Battle Position (Day) (LFX)
	Defend Battle Position (Night) (LFX)
	Movement to Contact (LFX)
	Movement to Contact
	Defend (to Retain) Battle Position
	Deliberate Night Attack
	Movement to Contact

MISSIONS CONDUCTED	
TF_____ conducted the following missions during their NTC training period:	
DATE	MISSION
	Deliberate Day Attack
	Deliberate Night Attack
	Defend in Sector
	Defend Battle Position
	Movement to Contact
	Delay in Sector
	Defend Battle Position (Day) (LFX)
	Defend Battle Position (Night) (LFX)
	Movement to Contact (LFX)

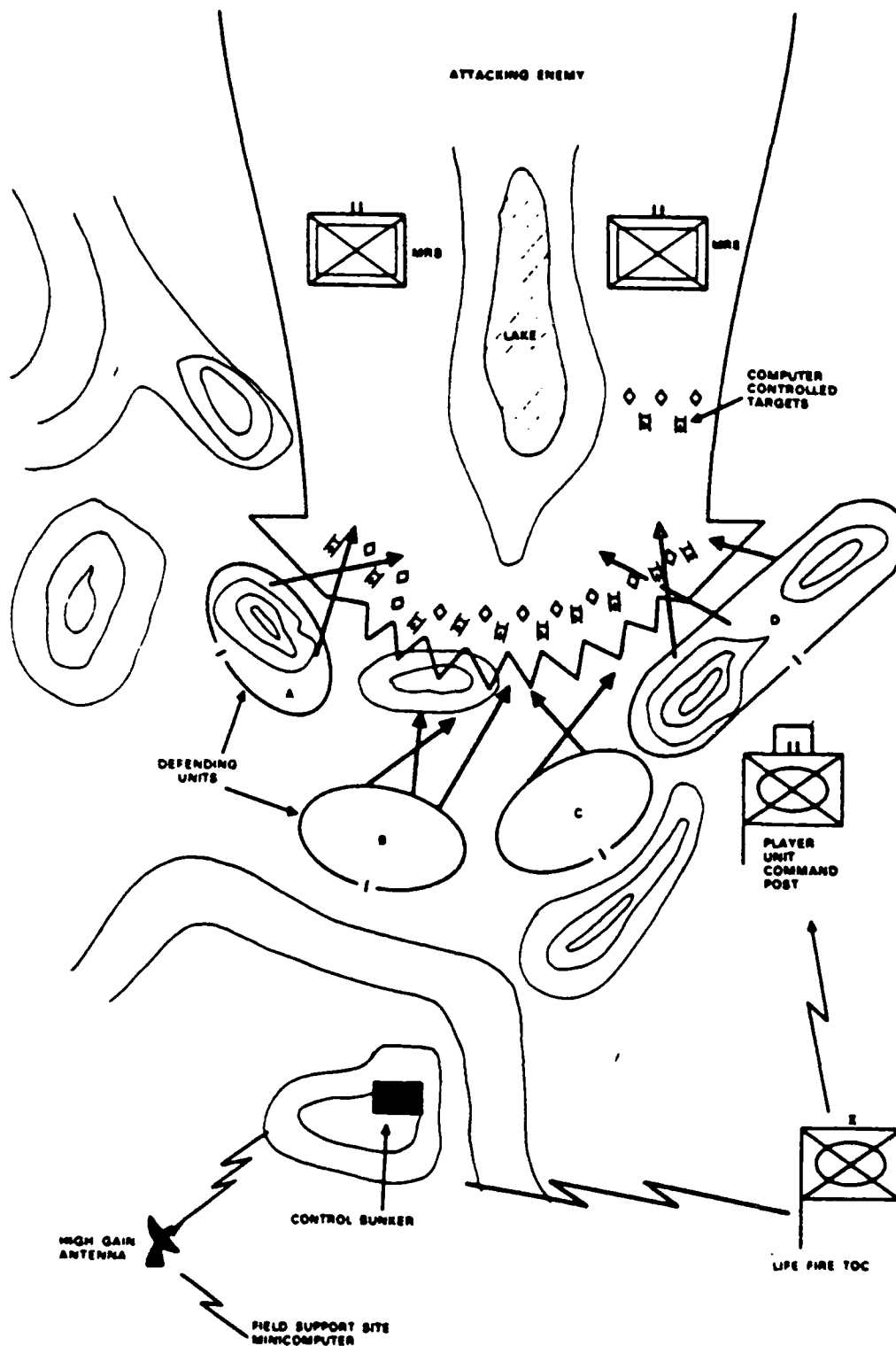


FIGURE 1. Live-Fire Defense Facility

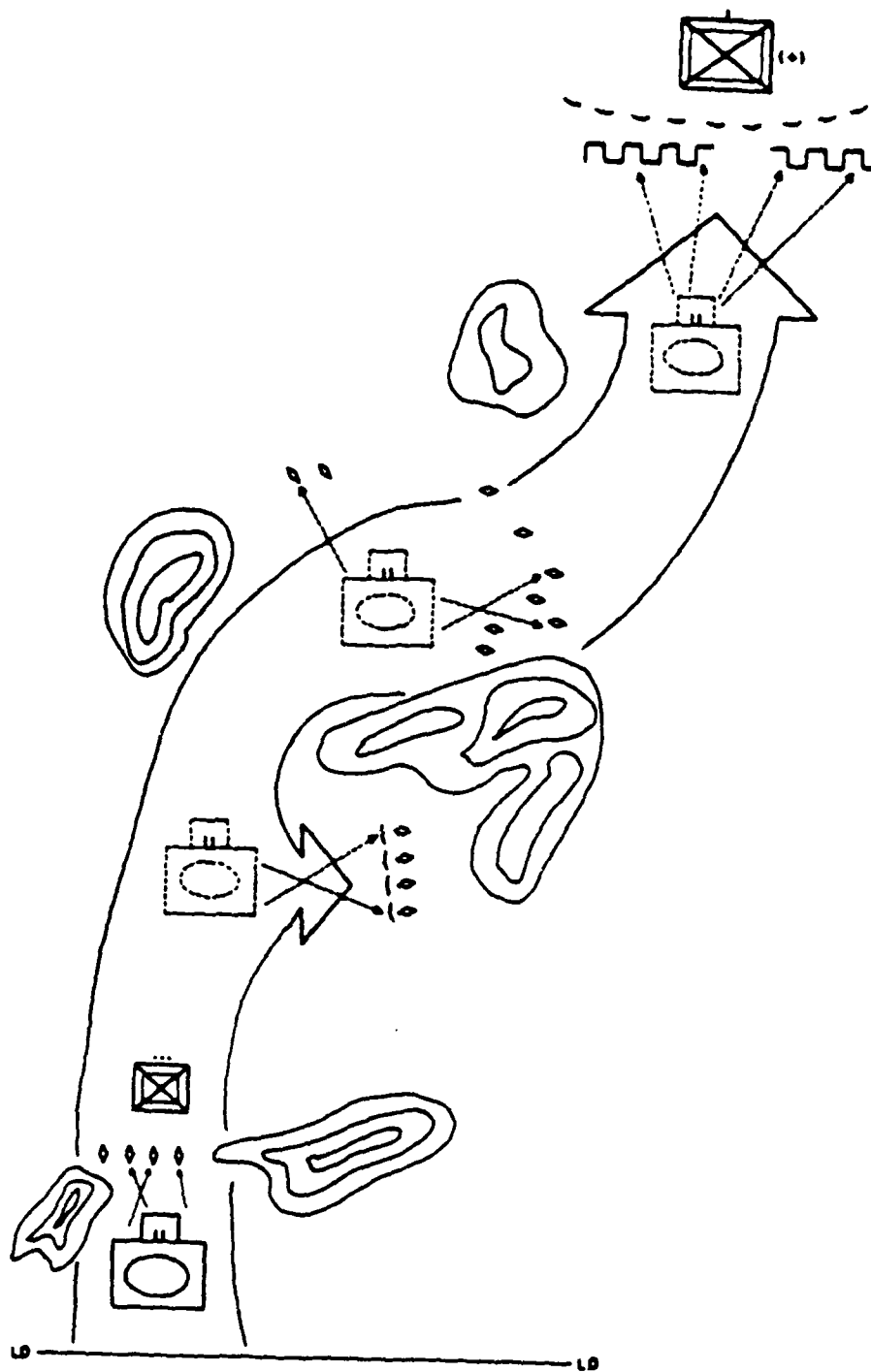


FIGURE 2. Live-Fire Offense Facility

PROCEDURES

This section of the report describes the technical approach used to investigate the three study issues. It has been organized into three sub-sections: Scope, Data Source, and Data Analysis. Each of these provides the technical details necessary to fully evaluate the results to be presented in the next section.

Scope

The live fire data used for this investigation were drawn from the battalions that went through the NTC in the period of early 1982 through late 1984. This period was selected because of the relative stability of the NTC training environment during that time. Information gathered through interviews with NTC personnel and a review of relevant NTC documents has indicated that the live-fire range was operated in a consistent manner for each battalion rotation during this period. (1) More specifically, the inquiry revealed the following information:

(1) The targets exposed were generally the same for each battalion; i.e., their distribution and presentation were presented in accordance with similar scenarios that allowed each battalion an equal opportunity to engage the targets under like conditions. The average number of targets exposed was slightly higher for each battalion during the second period, though this difference was statistically significant for only one of the three missions (see Table 1 for the individual significance test results).

(2) Each battalion generally occupied the same positions on the defensive missions and traveled the same route during the "Movement to Contact" mission. Thus, line of sight to the exposed targets was similar for all battalions (Figures 1 and 2 of this report present a schematic diagram of the general unit position locations with respect to target locations).

(3) The same procedures for scoring target hits and kills were followed throughout the 2-1/2 year period. Thus, hits and kills were credited in a consistent manner for each battalion rotation.

(4) A review of the observer controller comments in the Take Home Packages did not reveal any pertinent information concerning changes which might have influenced performance during this period.

Therefore, based on the above information, it was felt that performance in this period could be investigated with some confidence that factors external to the battalion task force were constant and not likely to be a major contributor to differential performance.

Data Source

The live-fire data were extracted from fifty-four (54) Take Home Packages (THP). These data represented the live-fire performances of 96% of the battalion task forces that trained at the NTC from early 1982 to late 1984. Data from the remaining 4% (2 battalions) of the task forces were either not available, or erroneous due to target equipment malfunctions on the live-fire range. It was felt that exclusion of this small amount of data from the investigation would not adversely affect its generalizability or statistical power.

The live-fire results reported in the THP generally included the following data.

- Number of Targets
- Percent of Targets Killed
- Tank Rounds Fired
- Tank Round Hits and Kills
- Tow/Dragon/Viper Laser Firings
- Tow/Dragon/Viper Laser Hits and Kills

These data presented ample opportunities for conducting preliminary research on battalion task force performances at the NTC. The performance data was first extracted from the Take Home Packages and consolidated onto tables as shown in Tables I-1 through I-3, Appendix I. Using these data, a computer data base was established to assist in sorting and analyzing the data. In all cases, unit designations were omitted to preserve unit anonymity.

Data Analysis

As indicated at the start of this report, an exploratory data analysis (Tukey, 1977) approach was employed in this study. This resulted in a series of analyses being conducted and all aimed at understanding the structure of the data from the live-fire range at the NTC. Specifically, analyses were aimed at satisfying the first two objectives of the exploratory data analysis approach (Hartwig and Dearing, 1979):

- (1) Understand each variable as a separate entity.
- (2) Understand pairs of variables as relationships.

A number of data analytic techniques were applied to the live-fire data base. The initial efforts used univariate descriptive statistical techniques. The results of these were used to generate a picture of performance at the NTC. Generally, the results were transferred into graphic display. Somewhat more sophisticated techniques including T-tests and regression were used to examine bivariate relationships between different factors and performance at the NTC. The results from these techniques have been tabled for inclusion in this report.

An important decision influencing the results contained in this report was the selection of a primary variable as measure of task force performance. Of the available variables, the one which seemed to most directly reflect overall unit performance was the PERCENTAGE OF ENEMY TARGETS KILLED.

It was also decided that because this report was designed to provide some early insights into unit performance changes at the NTC, only individual battalion performances would be considered and analyzed. That is, their performances would not be aggregated and analyzed at the brigade and division levels. However, an analysis of that order would be a logical follow-on to this analysis once a better understanding of the performance data at the battalion level is developed. For the same reason, only the effects of the tank ballistics are considered in this study although the performance of the Tows/Dragon/Viper laser firings on the live-fire range might also be investigated for a subsequent study. However, a review of the live-fire data in Appendix I shows that the tank ballistics data provides a more meaningful analysis due to the greater variability in that data as compared to the narrow range in values for the Tow/Dragon/Viper laser data.(2)

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RESULTS

As indicated in the introduction to the report, three issues were selected for investigation here. The results for each of the issues are presented separately, below. The conclusions based on these findings are presented in the subsequent section.

Has Battalion Task Force Performance Changed Over Time at the NTC?

The answer to this issue provides some insight into the possibility of improved battalion task force performance at the NTC. Clearly, if one views the NTC as a measuring stick for battalion performance then it is critical to know whether performance is getting better, worse, or staying the same.

This issue was addressed initially by examining the performance of all battalions that visited the NTC over time. Figures II-1 through II-6 in Appendix II show bar charts of the percent of targets killed by all battalions for the period early 1982 through late 1984. The data in these bar charts show a clear trend towards an increasing percentage of targets being killed in the latter period of the rotation schedule. The statistical summary of the live-fire performances supports the graphic depiction and is presented in Table 1, next page (in order to perform a statistical analysis of this trend, two periods were arbitrarily selected for comparison; e.g., the last 12 months of performance data was compared with the previous 18 month performance data).

As can be seen from Table 1, the units which trained at the NTC during the last 12 months had a higher average percent kill rate for all three missions than did those units which trained in the first 18 month period. The table shows that for the mission of "Defend from a BP (Day)", the combined percentage of targets killed by the Armor and mechanized units improved by 5.86% in the second period (from 29.95 % to 35.81%). In the "Movement to Contact" mission the improvement was 10.12% (from 28.47% to 38.59%). This difference was statistically significant at the $p < .01$ level.

A review of Table 1 also reveals a significant increase in the number of tank rounds being fired during the second period. This increase was statistically significant ($p < .01$) for both the offensive and night defensive missions. The number of targets also increased to some degree, though this was only significant ($p < .01$) for the night defensive mission. The importance of these factors are discussed later in this section.

The data used in the analysis reported above were derived from all the Battalion Task Forces in the study period. Some of

TABLE 1

Live-Fire Performance Summary of all Battalion Task Force Rotations (Armor and Mech Combined)

Mission		Defend from BP (Day)		Defend from BP (Night)		Movement to Contact (Day)	
		\bar{X}	SD	\bar{X}	SD	\bar{X}	SD
First Period (First 18 Mo's) (n=30)	% TGTS KILLED BY TANK RDS	29.95	15.56	11.17	9.35	**	8.32
	TANK RDS FIRED	189.72	100.75	**	80.27	**	155.32
	NO. OF TGTS EXPOSED	85.33	4.44	**	8.62	**	12.93
Second Period (Last 12 Mo's) (n=26)	% TGTS KILLED BY TANK RDS	35.81	12.45	14.33	10.10	**	14.10
	TANK RDS FIRED	231.96	110.90	**	98.07	**	168.61
	NO. OF TGTS EXPOSED	85.57	2.69	88.83	6.18	**	11.50
Statistical significance of difference between performances of first period and second period: * p < .05 ** p < .01							

3.16% Improvement

5.86% Improvement

10.12% Improvement

the battalion task forces were actually the same battalion on a repeat visit to the NTC while the remainder were one-time visitors to the NTC. To determine whether the apparent improvement over time was due to the repeat visits of certain battalions or to some other phenomenon, separate analyses were conducted for battalions that visited the NTC once versus those that made repeat NTC visits.

Performance of One-Time NTC battalions. Figures II-7 through II-12, Appendix II, present the bar charts of the percent of targets killed by the one-time visitors to the NTC. As with the above analysis of all battalions together, the one-time visitors to the NTC appear to have performed better in the latter period of the rotation schedule, particularly in the "Movement to Contact" offensive mission.

Comparing the last 12 months of performances with the earlier performances (Table 2, next page), we find increases in all three missions although none of the differences were statistically significant. The increases were 6.74% for the day defense (from 25.10% to 31.84%), 3.81% for the night defense (from 12.21% to 16.02%), and 9.5% for the offense (from 29.71% to 39.21%).

Performance of repeat performers at the NTC. There were thirteen (13) battalions with repeat visits to the NTC during the period under study. Twelve battalions had two rotations and one had three rotations for a total of 14 repeat performances. The average time lapse between repeat rotations was 15 months with the periods ranging from 8 to 21 months.(3)

Figures II-13 through II-15, Appendix II, present the bar charts of the performances of these 13 repeat NTC visitors. They show that of the 42 repeat performances (fourteen for each of the 3 missions), 24 showed improvement in the follow-on rotations, 4 showed no improvement, and 9 showed a decrease in subsequent performance. There were five cases where no data was available. The "Movement to Contact" mission showed the most cases of improved follow-on performances (11 out of 14 rotations). It should also be noted that 12 of the 14 repeat performances occurred in the last 12 months of the 2-1/2 year period under consideration.

The results of the statistical analysis of this data is presented in Table 3, page 17. The analysis compares the battalion's performance with its subsequent performance.

TABLE 2

Live-Fire Performance Summary of Battalion Task Forces With One-Time Rotations (Armor and Mech Combined)

Mission		Defend from BP (Day)		Defend from BP (Night)		Movement to Contact (Day)	
		\bar{X}	SD	\bar{X}	SD	\bar{X}	SD
First Period (First 18 Mo's) (n=15)	% TGTS KILLED BY TANK RDS	25.10	14.79	12.21	10.31	29.71	7.87
	TANK RDS FIRED	144.57	63.39	114.14	80.97	279.40	170.65
	NO. OF TGTS EXPOSED	85.80	6.19	82.93	3.90	61.29	15.73
Second Period (Last 12 Mo's) (n=14)	% TGTS KILLED BY TANK RDS	31.84	9.75	16.02	11.78	39.21	17.30
	TANK RDS FIRED	196.00	115.38	206.07	80.43	417.33	179.87
	NO. OF TGTS EXPOSED	86.18	3.03	88.46	6.01	67.08	15.42
Statistical significance of difference between performances of first period and second period * $p < .05$ ** $p < .01$							

6.74% Improvement

3.81% Improvement

9.5% Improvement

The results presented in Table 3, next page, show a slight improvement in the day and night defensive missions between first and subsequent rotational visits (+3.30% for the day defense, +0.48% for the night defense). However, the "Movement to Contact" mission shows a statistically significant increase (at the $p < .01$) of 11.66%. It is interesting to note that the one statistically significant improvement found in the analysis of all battalions together (Table 1) was for this same mission. In fact, the size of the increase is very similar (11.16% compared to 10.12%).

A comparison was made between the first performances of the battalions which had repeat visits to the NTC with the performances from one-time NTC battalions for the same approximate time period to see if the two groups could be considered comparable. This analysis produced no statistically significant ($p < .05$) results. Thus, it would appear that the two groups could be considered as similar and from the same statistical population.

The previous results clearly show that performance, as measured by the percent of targets killed, has increased at the NTC. Investigation of whether this might be due to the repeat visits of some of the battalions produced mixed results. That is, some statistical support for that notion was provided by the results for the "Movement to Contact" mission; however, no evidence was found for the other two missions. In fact, the difference in performance for one-time NTC battalions across the two periods was greater than that for the repeat battalions. It would seem, then, that the increase in performance cannot be attributed primarily to experience gained by repeat NTC visits.

TABLE 3

Live-Fire Performance Summary of Battalion Task Forces With Repeat Rotations (Armor and Mech Combined)

Mission		Defend from BP (Day)		Defend from BP (Night)		Movement to Contact (Day)	
		\bar{X}	SD	\bar{X}	SD	\bar{X}	SD
First Rotation (n=13)	% TGTS KILLED BY TANK RDS	34.56	15.80	11.06	8.36	** 26.13	8.20
	TANK RDS FIRED	238.86	113.16	161.00	87.70	* 326.86	140.49
	NO. OF TGTS EXPOSED	84.93	1.49	* 81.00	12.37	* 65.50	9.01
Subsequent Rotations (n=14)	% TGTS KILLED BY TANK RDS	37.86	13.98	11.54	7.87	** 37.79	9.94
	TANK RDS FIRED	248.93	115.34	227.38	110.57	* 485.29	166.35
	NO. OF TGTS EXPOSED	84.86	2.18	* 88.46	6.37	* 74.07	3.65
Statistical significance of difference between performances of first rotation and subsequent rotations: * p < .05 ** p < .01							

0.48% Improvement

3.30% Improvement

11.66% Improvement

How do the Performances of the Armor and Mechanized Infantry Task Forces Differ?

The second issue investigated in this report concerns the question of whether the Armor Task Forces and the Mechanized Task Forces have similar performance characteristics. Again, performance is examined across time and for all battalions, one-time battalions, and repeat battalions.

All battalions. When considered separately by Armor and Mechanized Infantry Task Forces (Table 4, next page), the combined performances of one-time visitors and repeat visitors in the second period continued to reflect improvement over the first period with the exception of the day defensive mission for the armor units which showed a slight decrease in the percent of targets killed. The overall improvement in the combined three missions for the mechanized units was 31.08% target kills as compared to 7.26% for the armor units (sum of the means of the second period minus sum of the means of the first period). The differences between the first and second periods of performance in the offensive and day defensive missions for the mechanized units were statistically significant at the $p < .05$ level. The data also reflected a higher percent of targets being killed by armor units throughout the two periods under study as evidenced by the total of the means for both type organizations.

Therefore, while the armor battalions averaged a higher percentage of target kills throughout the two periods, the mechanized infantry had a better improvement rate for those same two periods. (4)

One-time battalions. The investigation of the one-time NTC visitor performances, when analyzed separately by armor and mechanized units (Table 5, page 20), again shows an increase in the performances on all three missions by both types of units. Applying the same computational procedures used in the Table 4 discussion, we find that the largest improvement took place among the mechanized units (20.95% compared with 14.77% for armor). The armor units, however, killed a greater percentage of the targets over this period of time (an average of 28% kills for the armor units versus 22% kills for the mechanized units).

Repeat battalions. For battalions which visited the NTC more than once, the performances of the armor and mechanized units are reported in Table 6, page 21. The largest improvements occurred in the mechanized units (28.19% net improvement in the mechanized units versus 5.48% improvement in the armor units). Although the armor units again achieved a higher percent of target kills, their performance actually decreased in two of the three missions between first and subsequent rotational visits as noted at Table 6.

Possible causes for performance differences. One of the possible causes for the change in performance noted in the

TABLE 4

Live-Fire Performance Summary of All Battalion Task Force Rotations (Armor and Mech Separately)

I. Mechanized Infantry Task Forces

Mission		Defend from BP (Day)		Defend from BP (Night)		Movement to Contact (Day)	
First Period (First 18 Mo's) (n=19)	% TGTS KILLED BY TANK RDS	\bar{X}	SD	\bar{X}	SD	\bar{X}	SD
	
		21.76	8.35	8.18	7.09	24.11	7.56
	
Second Period (Last 12 Mo's) (n=12)	% TGTS KILLED BY TANK RDS	\bar{X}	SD	\bar{X}	SD	\bar{X}	SD
		34.24	16.00	13.43	7.03	37.46	15.39
	
		220.70	129.42	175.36	83.04	456.36	152.01
	NO. OF TGTS EXPOSED	\bar{X}	SD	\bar{X}	SD	\bar{X}	SD
		86.00	6.19	79.86	12.06	59.36	15.98
	
		85.80	2.90	88.75	5.51	72.91	8.96

$$\Sigma \bar{X} = 54.05\%$$

$$\Sigma \bar{X} = 85.13\%$$

$$\Sigma \bar{X} - \Sigma \bar{X} = +31.08\%$$

II. Armor Task Forces

Mission		Defend from BP (Day)		Defend from BP (Night)		Movement to Contact (Day)	
First Period (First 18 Mo's) (n=19)	% TGTS KILLED BY TANK RDS	\bar{X}	SD	\bar{X}	SD	\bar{X}	SD
		38.13	16.98	13.81	10.45	32.54	6.96
	
		231.93	101.33	164.93	78.91	404.20	139.33
Second Period (Last 12 Mo's) (n=13)	% TGTS KILLED BY TANK RDS	\bar{X}	SD	\bar{X}	SD	\bar{X}	SD
		37.03	9.41	15.16	12.55	39.55	13.48
	
		240.62	118.05	264.75	107.02	480.38	186.94
	NO. OF TGTS EXPOSED	\bar{X}	SD	\bar{X}	SD	\bar{X}	SD
		84.67	1.29	84.20	1.90	68.53	7.35
	
		85.38	2.63	88.92	7.03	68.31	13.26

$$\Sigma \bar{X} = 84.48\%$$

$$\Sigma \bar{X} = 91.74\%$$

$$\Sigma \bar{X} - \Sigma \bar{X} = +7.26\%$$

Statistical significance of difference between performance of first period and second period:

• p < .05
 •• p < .01

TABLE 5

Live-Fire Performance Summary of Battalion Task Forces With One-Time Rotation (Armor and Mech Separately)

I. Mechanized Infantry Task Forces

Mission		Defend from BP (Day)		Defend from BP (Night)		Movement to Contact (Day)	
First Period (First 18 Mo's) (n=8)	% TGTS KILLED BY TANK RDS	\bar{X}	SD	\bar{X}	SD	\bar{X}	SD
		20.67	7.60	8.99	6.34	26.07	5.36
		102.29	37.51	79.43	62.37	183.38	90.33
		87.00	8.49	82.25	4.95	93.43	18.27
Second Period (Last 12 Mo's) (n=9)	% TGTS KILLED BY TANK RDS	26.37	13.85	12.72	4.29	37.55	20.20
		180.00	178.91	153.60	47.61	382.00	171.49
		88.50	3.00	89.67	6.86	70.80	13.54

$$\Sigma \bar{X}_1 = 55.69\%$$

$$\Sigma \bar{X}_2 = 76.64\%$$

$$\Sigma \bar{X}_2 - \Sigma \bar{X}_1 = +20.95\%$$

II. Armor Task Forces

Mission		Defend from BP (Day)		Defend from BP (Night)		Movement to Contact (Day)	
First Period (First 18 Mo's) (n=7)	% TGTS KILLED BY TANK RDS	\bar{X}	SD	\bar{X}	SD	\bar{X}	SD
		30.15	19.67	15.48	12.86	33.35	8.62
		186.86	55.92	148.86	86.61	389.14	179.13
		84.43	1.13	83.71	2.36	69.14	7.63
Second Period (Last 12 Mo's) (n=7)	% TGTS KILLED BY TANK RDS	34.97	5.59	18.38	15.05	40.40	16.52
		209.14	76.90	243.43	80.17	442.57	194.74
		84.86	2.27	87.43	5.50	64.43	17.15

Statistical significance of difference between performance of first period and second period:

* $p < .05$
 ** $p < .01$

$$\Sigma \bar{X}_1 = 78.98\%$$

$$\Sigma \bar{X}_2 = 93.75\%$$

$$\Sigma \bar{X}_2 - \Sigma \bar{X}_1 = +14.77\%$$

TABLE 6

Live-Fire Performance Summary of Battalion Task Forces With Repeat Rotations (Armor and Mech Separately)

I. Mechanized Infantry Task Forces

	Mission	Defend from BP (Day)		Defend from BP (Night)		Movement to Contact (Day)	
		\bar{X}	SD	\bar{X}	SD	\bar{X}	SD
First Rotation (n=6)	% TGTS KILLED BY TANK RDS	23.67	10.33	8.33	10.38	19.44	6.45
	TANK RDS FIRED	195.67	98.35	69.67	10.69	213.83	88.46
	NO. OF TGTS EXPOSED	85.00	1.67	75.20	19.68	63.17	11.29
Subsequent Rotations (n=7)	% TGTS KILLED BY TANK RDS	31.40	17.53	10.80	7.88	37.43	11.09
	TANK RDS FIRED	210.60	90.72	176.00	42.01	469.43	164.92
	NO. OF TGTS EXPOSED	84.00	0.00	88.60	4.22	75.14	2.54

$$\Sigma \bar{X}_1 = 51.44\%$$

$$\Sigma \bar{X}_2 = 79.63\%$$

$$\Sigma \bar{X}_2 - \Sigma \bar{X}_1 = +28.19\%$$

II. Armor Task Forces

	Mission	Defend from BP (Day)		Defend from BP (Night)		Movement to Contact (Day)	
		\bar{X}	SD	\bar{X}	SD	\bar{X}	SD
First Rotation (n=7)	% TGTS KILLED BY TANK RDS	42.73	14.47	12.23	7.88	31.14	9.32
	TANK RDS FIRED	271.25	118.64	200.14	74.43	411.63	109.11
	NO. OF TGTS EXPOSED	84.88	1.46	84.63	1.41	67.25	7.19
Subsequent Rotations (n=7)	% TGTS KILLED BY TANK RDS	41.44	11.10	12.00	8.38	38.14	9.53
	TANK RDS FIRED	270.22	125.78	259.50	129.95	501.14	179.36
	NO. OF TGTS EXPOSED	85.33	2.65	88.38	7.71	73.00	4.43

$$\Sigma \bar{X}_1 = 86.10\%$$

$$\Sigma \bar{X}_2 = 91.58\%$$

$$\Sigma \bar{X}_2 - \Sigma \bar{X}_1 = +5.48\%$$

Statistical significance of difference between first rotation performance and subsequent rotations:

* $p < .05$
 ** $p < .01$

Decrease in Performance

analyses above is that the configuration of the task forces changed during the period under study. Specifically, the task forces began to convert from the H-series MTO&E to the J-series structure during the latter months of the 2-1/2 year period studied here. This conversion resulted in the addition of an average of seven tanks per Mechanized Infantry Task Force (the task force average went from 11.30% to 18.75%) during the last twelve months with the greatest change taking place during the last eight months. However, the conversion had little impact upon the strength of the Armor Task Forces where the average number of tanks increased by two tanks, going from 25.67 to 27.69 tanks.

The change in the number of tanks certainly contributed to the findings in paragraphs above which showed that the Armor Task Forces killed more targets but that the Mechanized Infantry Task Forces had a greater improvement record between the first and second periods. The impact of the number of tanks upon performance is discussed in the next section.

What Other Factors Seem to be Related to Performance at the NTC?

The analysis addressing the previous two issues provided not only a univariate understanding of NTC performance but also the relationship of that performance to two other factors: time and battalion task force type. This issue expands the investigation to two other factors which might influence or be related to NTC live-fire performance: gunnery accuracy and volume of fire. The results from the analysis of these factors are presented separately below.

Gunnery accuracy. Table 7, next page, presents the "rounds per hit" and "rounds per kill" data which represent the accuracy of the tank crews.

The data on the Mechanized Infantry Task Forces show an overall decrease, albeit slight, in accuracy between the first and second periods (0.73 additional rounds required per kill and 2.69 additional rounds per hit in the second period) while the Armor Task Forces show a slight increase in gunnery accuracy (2.04 fewer rounds required per kill and 2.94 fewer rounds required per hit in the second period). These slight differences between periods appear to rule out increased accuracy as a major reason for the increased performance between the two periods. In fact, none of the statistical comparisons between the two time periods produced significant differences. Therefore, it seems unlikely that gunnery accuracy is a factor contributing to the change in performance observed in the earlier data.

TABLE 7

Comparison of Rounds Per Hit and Rounds Per Kill For Armor and Mechanized Task Forces

I. Mechanized Infantry Task Forces								
First Period (First 18 mo's) n=15	Mission:	Defend from BP (Day)		Defend From BP (Night)		Movement to Contact (day)		Mean of
		\bar{X}	SD	\bar{X}	SD	\bar{X}	SD	\bar{X}
	Rds/Kill	7.81	3.35	21.83	30.35	14.53	5.26	14.72
	Rds/Hit	3.40	1.64	7.62	6.28	7.14	3.29	6.05
Second Period (Last 12 mo's) n=16	Rds/Kill	9.03	7.62	18.55	11.75	18.77	6.60	19.45
	Rds/Hit	5.34	4.42	11.96	9.08	8.93	3.74	8.74
II. Armor Task Forces								
First Period (First 18 mo's) n=15	Mission:	Defend from BP (Day)		Defend From BP (Night)		Movement to Contact (day)		Mean of
		\bar{X}	SD	\bar{X}	SD	\bar{X}	SD	\bar{X}
	Rds/Kill	8.39	4.63	36.14	55.36	18.43	5.97	20.99
	Rds/Hit	3.72	2.22	28.98	55.05	8.70	3.11	13.80
Second Period (Last 12 mo's) n=16	Rds/Kill	7.61	3.37	29.93	18.91	19.30	6.70	18.95
	Rds/Hit	3.67	1.06	19.46	13.23	9.46	6.10	10.86

+0.73

+2.69

-2.04

-2.94

Volume of fire. The second area investigated as a possible factor relating to the change in percentage of targets killed was the volume of fire. This area was examined using two different but related measures. The first was the absolute number of tank rounds fired per mission. This measure provides an overall indication of the volume of fire for any particular live-fire mission. However, since the volume of fire measured in this way is clearly dependent upon the number of tanks (which changed during the study period), a second measure, number of tank rounds fired per tank, was also analyzed. This measure which controlled for the number of tanks participating on a mission provided a better comparative yardstick for investigating the relationship between volume of fire and percentage of targets killed.

The initial step in investigating volume of fire was to determine whether it had changed over time at the NTC. Table 8 below is an extract from Table 3 showing the number of rounds fired by all Armor and Mechanized Infantry Task Forces in the first and second periods. The number of rounds increased quite dramatically from the first to second period for each mission (the differences are statistically significant for three of the six cases). The greatest increase in rounds fired was in the "Movement to Contact" mission. The average increase in number of rounds fired by the Mechanized Infantry Task Forces was higher than that of the Armor Task Forces (+141.86 for Mechanized Infantry compared to +61.56 for Armor).

TABLE 8

Comparison of Tank Rounds Fired Between First and Second Periods

TIME PERIOD	TF	DEFENSE MISSION (DAY)	DEFENSE MISSION (NIGHT)	OFFENSE MISSION (DAY)	MEAN OF \bar{X}
		\bar{X}	\bar{X}	\bar{X}	
FIRST PERIOD (FIRST 18 MO'S)	M	144.50	87.27	195.07	142.28
	A	231.93	164.93	404.20	267.02
SECOND PERIOD (LAST 12 MO'S)	M	220.70	175.36	456.36	284.14
	A	240.62	264.75	480.38	328.58

+141.86 Rounds

+61.56 Rounds

Statistical significance of difference in \bar{X} 's between first and second periods:
 * $p < .05$
 ** $p < .01$

The increase in volume of fire noted here was at least partially due to the increase in the number of tanks between the two periods. However, it was also possible that an increase in the rounds fired per tank may have contributed. To investigate whether this was the case, the rounds per tank for the two periods were compared.

This comparison showed that indeed the average number of rounds per tank increased over the two time periods. Specifically, the Mechanized Task Force increased from 12.93 rounds per tank to 15.61 in the second period. The Armor Task Force also increased by slightly less than two rounds per tank (going from 10.51 to 12.04). Both of these changes were statistically significant ($p < .05$). Thus, the increase in total fire volume can be seen to be due both to the increase in tanks and an increase in rounds per tank.(5)

The above results show that an increase in targets killed coincided with an increase in tanks and an increase in rounds fired. This suggests that an increased volume of fire per tank may provide for an increased percentage of target-kills. To explore this further, an analysis of the association between the number of rounds fired per tank by each battalion with that battalion's target kill percentage was performed. The purpose of this analysis was to investigate whether there was statistical credence for a relationship between performance and rounds fired per tank when controlling for the variance in the number of tanks across the battalion. Note that unlike previous analyses, the time period was not directly a consideration in this analysis although that variable is addressed in the Figures and discussion below.

Separate analyses were conducted for each mission. The results of the analysis of all three missions are included in Figures III-1, III-2, and III-3 in Appendix III. The analysis took the form of a two variable regression using, as indicated above, the percent of targets killed and the number of rounds fired per tank for a battalion.(5) The results from this analysis provide an indication of the nature of the relationship between these two variables and could potentially be used for eventual prediction of battalion performance in the future.

For the offensive mission a statistically significant and positive relationship was found between the average number of rounds fired per tank and the percent of targets killed by that battalion. The regression analysis produced a line depicted in Figure III-1, page III-1. As can be seen, the slope of the line is positive, indicating that the greater the number of rounds fired per tank, the greater the percent of targets killed. Specifically, the slope indicates that an increase in one round fired per tank throughout a battalion results in .75 percent more targets killed for that battalion. Thus, there was somewhat less than a one-to-one relationship between the number of rounds fired and the percent of targets killed. It should be noted that the

number of rounds fired explained 17% (statistically significant $P < .01$) of the variability in the performance observed in the percent of targets killed by battalions at the NTC.

Similar and somewhat stronger results were found for the day defend mission as can be seen in Figure III-2, page III-3. Again, the results were statistically significant ($P < .01$) with a positive slope between the two variables. The slope of this line is such that for each incremental increase of one round per tank throughout the battalion, there is an increase of some 1.5% of targets killed for that battalion. Thus, for this mission, a greater than one-to-one return is achieved on the incremental round per tank. Further, the regression of this single variable accounts for slightly more than 20% of the total variation in the percent of targets killed.

The results for the night defend mission, Figure III-3, page III-5, were not quite as strong as for the previous two missions, though they were still statistically significant ($p < .05$). In this case the regression of the number of rounds fired per tank accounted for about 10% of the total variability in the percent of targets killed. It is interesting to note that the slope of this regression line (.984) indicated that with each additional round fired per tank that one could expect about an additional one percent additional loss of enemy targets. Lastly, an examination of the plot of this relationship shows that part of the lower predictability for this mission is probably a result of the skewed distribution for rounds fired per tank. This distribution is positively skewed with most of the observations having values falling between 4 and 10 rounds per tank. To some extent this skewness is probably attenuating the correlation between these two variables.

Although these data were analyzed independent of the chronological event, the plots indicate the time period for each data point; i.e., the symbol 1 indicates units from the first period (first 18 months) and the symbol 2 indicates units from the second period (last 12 months). Using the intercept of the means for the number of rounds per tank and the percent of targets killed as a comparison point (denoted in the Figures by a "+"), we find that:

- (1) In the offensive mission, 13 of the 16 battalions that exceeded both means were from the second period;
- (2) For the day defensive mission, 10 of the 14 battalions that exceeded both means were from the second period, and;
- (3) In the night defensive mission, 10 of the 14 battalions which exceeded the means were from the second period.

It is apparent from these analyses that volume of fire, as measured by the rounds per tank for a battalion, is positively related to the percentage of targets killed. This implies that a unit with higher rounds per tank will achieve greater results at the NTC. The translation of this finding into practice is something which requires additional study at the process level.

CONCLUSION

Using the "percentage of target kills" data as an indicator of meaningful unit performance on the live-fire range at the NTC and comparing the battalion performances in the first 18 months with those of the next 12 months of a 2 1/2 year period (early 1982 to late 1984), this study found that:

(1) The percent of targets killed by the tanks of the Armor and Mechanized Infantry Task Forces increased between the first and second periods of this study.

(2) The increase in percent of targets killed between the first and second periods was attributable to both one-time visitors to the NTC and to repeat visitors to the NTC. Therefore, the differences in performance was a function of some phenomena associated with time and not just some advantage factor acquired through repeat visits to the NTC as might be expected.

(3) The change in performances on the live-fire ranges was probably not a function of the activities involved in the operation of the live-fire range by NTC cadre; i.e., the live-fire exercises were conducted in a uniformly consistent manner throughout the 2-1/2 year period of this study.

(4) The change in percent of target-kills over time was not related to gunnery accuracy as this did not change over time. However, a significant increase in the volume of tank rounds fired by both the Armor and Mechanized Infantry Task Forces in the second period was likely related to the observed increase in target kills.

(5) The increase in rounds fired was related to an increase in number of tanks assigned to the task forces (particularly to the mechanized units) in the second period and to an increase in the number of rounds fired per tank.

(6) A positive and statistically significant relationship was found between the number of rounds fired per tank and the percent of enemy killed. This relationship was strongest for the day attack and day defend missions.

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END NOTES

1. Information provided through an interview with the former Chief of NTC Operations Group, Col. (Ret.) Shackelford, who held the position during the period covered by this report: Report entitled "National Training Center Perspectives, February 8, 1985": Take Home Packages.

2. The Hit and Kill data of the TOW's/DRAGON/VIPER laser firing weapons reflected sub-par performances as compared to the tank ballistics. Although gunnery skills may have had a bearing on that outcome, the problems associated with the inability of the laser to penetrate smoke and dust on the live-fire range probably had a significant impact on the overall performances of these weapons systems.

3. A two-way analysis of variance was performed for each mission employing type of unit (Mechanized Infantry or Armor) and time period (first 18 months versus last 12 months) as the two factors in the design. The time period factor was statistically significant ($p < .05$) for all three missions. The type of unit factor was found to be statistically significant ($p < .01$) only for the day defensive mission. The interaction effect was not significant in any of the analyses.

4. While the employment of a measure which incorporates the number of tanks into its calculation should control the influence of that term, two analyses were conducted to determine the degree of that control. First, correlations between number of tanks and rounds per tank were computed. These were done for all missions and time periods. With one exception (Year 2 day attack mission $r = -.48$), the correlations were not significantly different from zero. Further, an analysis of covariance was performed using number of tanks as a covariate, time period as the independent factor and rounds per tank as the dependent measure. The results of these analyses parallel those for the T-tests on time period reported in the body of this report.

5. A multiple regression analysis by mission was also performed. The model included number of tanks and rounds per tank, the results of these analyses indicated a better overall fit to the data than that for the simple bivariate regression reported in the text. The squared multiple correlation coefficients for the three missions (Day Attack, Day Defend, and Night Defend) were .35, .53, and .13 respectively. Each of these was statistically significant, with the first two exceeding the .01 level and the last satisfying the .05 level. The improvement in fit (as measured by the increase in proportion of variance accounted for) was 18%, 33%, and 3%. The first two of these were statistically significant.

The focus of the present discussion on rounds per tank is consistent with the intent of these analyses to uncover factors related to performance which might possibly be influenced by training.

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REFERENCES

Hartwig, F. with Dearing, B.E. Exploratory Data Analysis. Beverly Hills, CA: Sage, Inc. 1979.

Letter. Subject: Observer Controller (OC) Standard Operating Procedures (SOP). HQ National Training Center and Fort Irwin, CA (Department of the Army). Undated.

Shackelford, W.L. NTC Perspectives. BDM Corporation Proprietary Report, Monterey, CA. 1985.

Tukey, J. Exploratory Data Analysis. Reading, MA: Addison-Wesley, Inc. 1977.

APPENDIX I - PERFORMANCE TABLES

Table I-1

Performance Data for Defensive Mission (Day)

LIVE-FIRE (DEFENSE)

DEFEND FROM A BATTLE POSITION (DAY MISSION)

NO.	DA TF	NO. TOTS	TANK BALLISTICS							TON/BRAND/VIPER LAZER					
			Z KILLED BY TANKS	TANK RDS FIRED	HITS	RDS/HIT	KILLS	RDS/KILL		Z KILLED BY T/B/V	T/B/V RDS FIRED	HITS	RDS/HIT	KILLS	RDS/KILL
1	A	06	43	293	151	1	37	5		7	n/a	6	n/a	6	n/a
	A	06	37	256	109	2	32	8		n/a	99	n/a	n/a	n/a	n/a
2	A	04	26	187	57	3	22	9		2	9	6	2	2	5
	A	04	7	78	19	4	6	12		33	128	79	2	28	5
3	A	04	24	182	102	1	28	5		4	36	7	5	3	12
	A	04	18	181	28	4	15	7		2	82	11	7	2	41
4	A	08	48	248	118	2	35	7		2	37	3	12	2	19
	A	04	12	128	34	4	18	12		1	178	2	89	1	178
5	A	04	29	185	41	5	24	8		4	43	9	5	3	14
	A	08	24	316	46	7	21	15		3	84	16	5	3	28
6	A	04	7	134	15	9	6	22		2	19	4	5	2	18
	A	04	21	182	48	2	18	6		5	148	15	9	4	35
7	A	04	56	329	126	3	47	7		4	14	14	1	3	5
	A	04	26	264	61	4	22	12		17	n/a	24	n/a	14	n/a
8	A	05	41	233	65	4	35	7		1	43	9	5	1	43
	A	04	14	n/a	32	n/a	12	n/a		2	n/a	15	n/a	2	n/a
9	A	04	19	172	23	7	16	11		4	93	22	4	3	31
	A	04	19	133	23	6	16	8		16	132	31	4	13	18
10	A	04	64	262	98	3	54	5		2	26	5	5	2	13
	A	04	58	167	38	4	25	7		5	122	12	18	4	31
11	A	04	58	338	95	6	42	13		8	33	16	2	7	5
	A	04	58	143	33	4	25	6		12	116	29	4	18	12
12	A	04	38	173	68	3	32	5		5	48	7	6	4	18
	A	04	18	63	42	2	15	4		12	71	28	4	18	7
13	A	04	45	218	113	2	38	6		1	15	8	2	1	15
	A	04	26	94	77	1	22	4		18	182	26	4	15	7
14	A	04	67	258	88	3	56	5		2	25	11	2	2	13
	A	04	31	146	48	2	26	6		27	118	54	2	23	5
15	A	07	23	237	52	5	28	12		8	3	3	1	8	8
	A	108	15	48	24	2	14	3		5	186	23	5	5	21
16	A	04	26	95	42	2	22	4		8	34	8	4	7	5
	A	04	15	78	24	3	13	6		8	116	12	18	7	17
17	A	04	48	178	61	3	34	5		1	9	1	9	1	9
	A	n/a	n/a	n/a	n/a	n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a	n/a
18	A	04	31	386	181	4	26	15		1	12	12	1	1	12
	A	04	8	288	12	17	7	38		6	133	6	22	5	27
19	A	04	28	188	43	3	17	6		2	48	4	18	2	28
	A	04	42	297	58	6	35	8		4	23	11	2	3	8
20	A	04	38	185	67	3	32	6		n/a	n/a	:	n/a	1	n/a
	A	04	37	189	48	2	31	4		2	79	5	16	2	48
21	A	04	58	289	58	4	25	8		8	16	8	8	8	8
	A	04	51	386	88	4	43	7		8	63	1	63	8	8
22	A	04	57	398	188	4	48	8		2	188	5	28	2	58
	A	04	49	232	98	3	41	6		5	123	25	5	4	31
23	A	04	38	168	34	5	32	5		2	43	2	22	2	22
	A	04	58	333	64	5	42	8		1	193	2	53	1	193
24	A	04	32	351	75	5	27	13		8	52	8	8	8	8
	A	n/a	n/a	n/a	n/a	n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a	n/a
25	A	04	48	284	57	4	34	6		4	29	3	18	3	18
	A	n/a	n/a	n/a	n/a	n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a	n/a
26	A	08	47	462	88	5	42	11		1	188	5	22	1	188
	A	08	44	448	185	4	48	11		7	166	14	12	5	28
27	A	08	41	168	71	2	37	4		2	28	2	14	2	14
	A	08	16	188	17	6	14	7		3	131	4	33	3	44
28	A	08	48	222	46	5	36	6		4	4	4	1	4	1
	A	08	58	94	33	1	27	3		18	81	15	5	9	9
MEANS			85	298	61	4	28	8		5	69	12	11	5	24

n/a = not available

Table 1-2

Performance Data for Defensive Mission (Night)

LIVE-FIRE (DEFENSE)

DEFEND FROM A BATTLE POSITION (NIGHT MISSION)

DDE	DN TF	NO. TOTS	TANK BALLISTICS							TOW/BRADON/VIPER LASER					
			1 KILLED BY TANKS	TANK RPS FIRED	HITS	RPS/HIT	KILLS	RPS/KILL		1 KILLED BY T/O/V	T/O/V RPS FIRED	HITS	RPS/HIT	KILLS	RPS/KILL
1	A	04	n/a	n/a	n/a	n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a	n/a
	A	40	n/a	n/a	n/a	n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a	n/a
2	A	79	1	31	1	31	1	31		0	3	0	0	0	0
	A	04	n/a	n/a	n/a	n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a	n/a
3	A	04	23	92	45	2	21	4		4	16	0	2	3	5
	A	04	20	63	44	1	17	4		4	12	10	1	5	2
4	A	00	26	164	81	2	23	7		2	30	4	10	2	19
	A	04	13	50	22	2	11	5		1	20	1	20	1	20
5	A	04	16	106	17	11	13	14		5	13	10	1	4	3
	A	n/a	n/a	n/a	n/a	n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a	n/a
6	A	04	6	70	5	14	5	14		2	21	4	5	2	11
	A	04	19	43	10	2	16	3		2	51	4	9	2	26
7	A	04	1	212	1	212	1	212		1	16	1	16	1	16
	A	04	0	04	0	0	0	0		2	34	9	4	2	17
8	A	05	6	151	7	22	5	30		1	63	2	32	1	63
	A	04	5	12	6	2	4	3		1	25	2	13	1	25
9	A	04	14	261	27	10	12	22		0	15	2	0	0	0
	A	04	2	195	13	15	2	90		2	09	2	45	2	45
10	A	04	12	100	26	4	10	10		0	5	0	0	0	0
	A	04	5	02	5	16	4	21		0	30	0	0	0	0
11	A	04	11	325	16	20	9	36		1	30	3	10	1	30
	A	04	5	127	9	14	4	32		0	65	2	33	0	0
12	A	04	10	127	12	11	0	16		2	53	3	10	2	27
	A	04	0	62	0	0	0	0		0	60	0	0	0	0
13	A	04	26	235	59	4	22	11		1	32	1	32	1	32
	A	04	n/a	n/a	n/a	n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a	n/a
14	A	04	33	160	04	2	20	6		1	10	1	10	1	10
	A	04	10	65	14	5	0	0		4	167	0	21	3	56
15	A	07	2	105	3	62	2	93		0	2	0	0	0	0
	A	70	11	197	19	10	0	25		0	06	0	0	0	0
16	A	04	10	155	36	4	15	10		0	14	0	0	0	0
	A	04	14	77	23	3	12	6		4	60	4	17	3	23
17	A	104	3	150	5	30	3	50		0	7	0	0	0	0
	A	n/a	n/a	n/a	n/a	n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a	n/a
18	A	04	10	401	14	24	0	60		1	10	1	10	1	10
	A	04	0	197	0	25	7	20		1	60	2	34	1	60
19	A	91	5	203	7	40	5	57		1	25	6	4	1	25
	A	91	13	163	17	10	12	14		0	05	0	0	0	0
20	A	06	26	210	49	4	22	10		0	23	0	0	0	0
	A	92	0	109	13	0	7	16		1	79	1	79	1	79
21	A	92	5	122	5	24	5	24		0	13	0	0	0	0
	A	92	23	216	40	5	21	10		0	60	0	0	0	0
22	A	04	16	171	19	9	13	13		1	03	3	20	1	03
	A	04	5	155	5	31	4	39		0	110	1	110	0	0
23	A	04	49	204	41	7	41	7		0	23	0	0	0	0
	A	04	27	321	51	6	23	14		0	44	0	0	0	0
24	A	04	11	333	19	10	9	37		0	52	0	0	0	0
	A	04	16	162	26	6	13	12		0	01	0	0	0	0
25	A	04	13	295	21	14	11	27		2	34	2	17	2	17
	A	n/a	n/a	n/a	n/a	n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a	n/a
26	A	90	20	100	23	11	10	22		0	120	0	0	0	0
	A	90	14	179	19	9	13	14		0	39	0	0	0	0
27	A	n/a	n/a	n/a	n/a	n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a	n/a
	A	90	14	147	21	7	14	10		0	00	0	10	0	0
28	A	90	7	295	0	27	7	42		11	15	13	1	11	1
	A	90	5	203	10	20	5	41		2	50	2	15	2	15
MEANS		05	12	174	21	17	11	26		1	44	2	13	1	15

n/a=not available

Table I-3

Performance Data for Offensive Mission (Day)

LIVE-FIRE (OFFENSE)

REPORT TO CONTACT (DAY MISSION)

DOE	DO TY	NO. TOTS	TIME BALLISTICS							TON/BRAND/TYPER LABEL					
			2 KILLED BY TANKS	TANK RPS FIRED	RITS	RPS/RIT	KILLS	RPS/KILL		2 KILLED BY T/O/V	T/O/V FIRED	RITS	RPS/RIT	KILLS	RPS/KILL
1	A	54	33	334	40	9	19	19		2	n/a	2	n/a	1	n/a
	R	60	26	252	29	9	10	14		n/a	n/a	n/a	n/a	n/a	n/a
2	A	54	20	400	26	16	15	27		2	12	1	12	1	12
	R	56	16	130	16	0	0	16		11	04	15	6	6	16
3	A	73	32	246	39	6	23	11		12	16	16	1	9	2
	R	70	21	277	49	6	15	10		30	00	00	1	21	2
4	A	73	29	439	49	9	21	21		n/a	n/a	n/a	n/a	n/a	n/a
	R	37	22	179	37	5	0	22		24	72	17	4	9	0
5	A	80	31	346	40	7	10	19		22	32	26	1	13	2
	R	66	23	300	32	10	15	21		30	204	54	4	25	0
6	A	74	26	90	33	3	19	5		12	16	13	1	9	2
	R	56	10	134	25	5	10	13		10	30	17	2	10	4
7	A	72	40	662	50	11	29	23		19	24	24	1	14	2
	R	75	23	234	29	0	17	14		23	123	37	3	17	7
8	A	71	27	372	34	11	19	20		17	32	30	1	12	3
	R	35	31	197	20	7	11	10		29	47	17	3	10	5
9	A	60	31	315	51	6	21	15		19	20	27	1	13	2
	R	70	30	176	50	4	20	6		10	41	10	4	0	5
10	A	70	23	427	37	12	16	27		19	24	23	1	13	2
	R	44	9	02	5	16	6	21		0	30	0	0	0	0
11	A	72	33	370	67	7	24	16		15	24	10	1	11	2
	R	33	27	120	14	9	9	13		30	37	22	2	10	4
12	A	74	36	361	56	6	27	15		10	154	26	6	13	12
	R	76	32	372	59	6	24	16		21	43	26	2	16	3
13	A	66	36	350	63	9	24	23		32	105	30	4	21	5
	R	n/a	n/a	64	30	2	10	4		n/a	116	00	3	17	7
14	A	72	51	501	67	9	37	16		0	0	0	0	0	0
	R	67	30	205	39	5	20	10		16	104	24	4	11	9
15	A	77	30	526	40	11	23	23		10	63	32	2	0	0
	R	70	23	196	26	0	16	12		11	54	23	2	0	7
16	A	72	11	100	17	11	0	24		19	n/a	31	n/a	14	n/a
	R	76	12	269	17	16	9	20		26	n/a	49	n/a	27	n/a
17	A	77	10	136	34	9	14	24		0	10	10	1	6	2
	R	n/a	n/a	n/a	n/a	n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a	n/a
18	A	77	29	496	35	9	20	17		14	72	16	5	11	7
	R	74	19	341	31	11	14	24		10	160	16	11	13	15
19	A	77	40	297	63	5	31	10		12	25	14	2	9	3
	R	77	39	301	02	7	30	19		14	24	11	2	11	2
20	A	75	37	514	112	5	43	12		5	4	4	1	4	1
	R	77	47	429	112	4	36	12		0	52	13	4	6	9
21	A	43	47	296	40	7	20	15		n/a	n/a	n/a	n/a	n/a	n/a
	R	76	39	595	60	10	30	20		17	03	13	6	13	6
22	A	69	46	649	102	6	32	20		15	96	22	4	10	10
	R	73	52	634	127	5	30	17		16	130	30	4	12	11
23	A	60	35	750	27	20	24	32		12	11	9	1	0	1
	R	71	20	530	36	15	20	27		23	53	17	3	16	3
24	A	39	46	293	50	6	10	16		0	11	11	1	3	4
	R	67	32	260	20	0	15	17		19	41	20	1	9	1
25	A	60	29	510	43	12	20	26		21	30	25	1	14	3
	R	n/a	n/a	n/a	n/a	n/a	n/a	n/a		n/a	n/a	n/a	n/a	n/a	n/a
26	A	66	44	772	71	11	29	27		17	67	21	3	11	6
	R	75	50	677	94	7	34	20		15	05	15	6	10	0
27	A	71	44	597	90	7	31	19		13	12	12	1	9	1
	R	75	32	320	44	7	24	14		25	70	41	2	19	4
28	A	06	57	530	01	7	49	12		10	9	9	1	9	1
	R	01	67	376	54	7	54	7		10	66	16	4	0	0
MEANS			67	33	275	49	9	22		16	54	21	3	11	5

n/a = not available

Table I-4

Rounds Fired Per Tank Per Battalion

Mission:		Defend (Day)	Defend (Night)	Offense (Day)
		\bar{X} of Rounds Fired/Tank	\bar{X} of Rounds Fired/Tank	\bar{X} of Rounds Fired/Tank
BDE	TF			
1	1A	8.4583	N/A	14.7500
	1M	19.6923	N/A	19.3846
2	2A	8.9048	1.4762	19.4286
	2M	4.6667	N/A	8.6667
3	3A	5.6667	5.1111	13.6667
	3M	9.1818	5.7273	25.1818
4	4A	8.2667	5.5333	14.6333
	4M	8.5714	3.5714	12.7857
5	5A	8.8095	8.8571	16.4762
	5M	35.1111	N/A	34.2222
6	6A	5.5833	2.9167	4.0833
	6M	11.3333	4.7778	14.8889
7	7A	12.6538	8.1538	25.4615
	7M	26.4000	6.4000	23.4000
8	8A	8.3214	5.3929	13.2857
	8M	N/A	1.0909	17.9091
9	9A	6.3704	9.6667	11.6667
	9M	10.2308	15.0000	13.5385
10	10A	9.0345	3.4483	14.7241
	10M	13.9167	10.4839	6.8333
11	11A	17.3548	11.5455	12.1935
	11M	13.0000	11.5455	10.9091
12	12A	5.9655	4.3793	12.4483
	12M	5.7273	5.6364	33.8182
13	13A	8.0741	8.7037	20.3704
	13M	9.4000	N/A	6.4000
14	14A	12.9000	8.4000	29.0500
	14M	11.2308	5.0000	15.7692
15	15A	7.9000	6.1667	17.5333
	15M	3.2000	13.1333	13.0667
16	16A	3.9583	6.4583	7.8333
	16M	6.0000	5.9231	20.6923
17	17A	4.8108	4.0541	9.0811
	17M	N/A	N/A	N/A
18	18A	13.3103	16.5862	17.1034
	18M	17.3333	16.4167	28.4167
19	19A	5.4000	14.1500	14.8500
	19M	14.8500	8.1500	29.0500
20	20A	5.7813	6.8125	16.0625
	20M	7.7857	7.7857	30.6429
21	21A	7.7407	4.5185	10.9630
	21M	13.0991	9.8182	27.0455
22	22A	14.2143	6.1071	23.1786
	22M	10.0870	6.7391	27.5652
23	23A	6.0000	10.1429	27.1071
	23M	12.8846	12.3462	20.3846
24	24A	14.0400	13.4000	11.7200
	24M	N/A	7.3636	11.8182
25	25A	7.1034	10.1724	17.5862
	25M	N/A	N/A	N/A
26	26A	17.1111	14.3704	28.5926
	26M	21.3333	8.5238	32.2381
27	27A	5.9259	N/A	22.1111
	27M	9.0909	13.3636	29.8182
28	28A	8.2222	10.9259	19.9259
	28M	4.4762	9.6667	17.9048

APPENDIX II

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PERFORMANCE BAR CHARTS

BATTALION TASK FORCE LIVE-FIRE PERFORMANCE PROFILE
MISSION: DEFEND FROM A BATTLE POSITION (DAY)

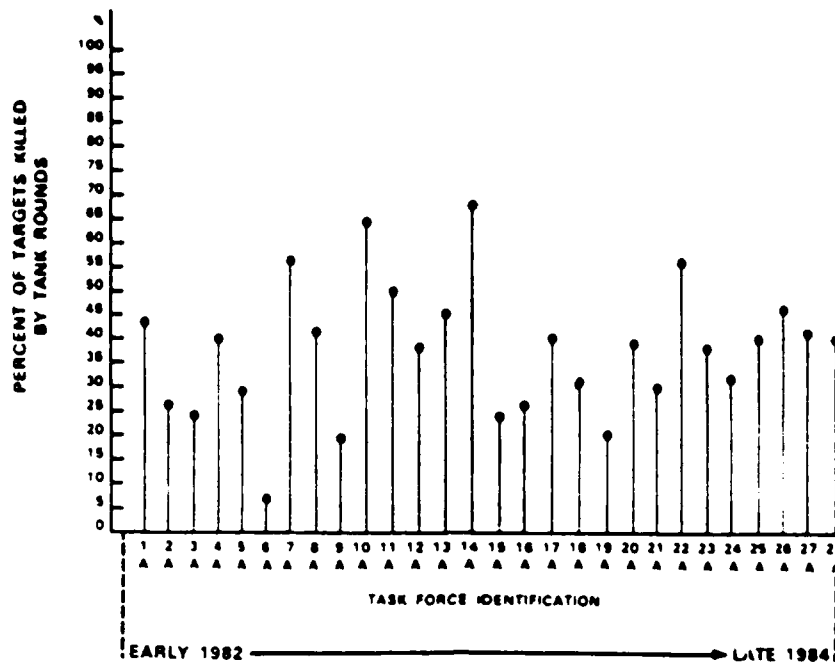


Figure II-1 Performance of all Armor Task Force Rotations in the Defense (Day)

BATTALION TASK FORCE LIVE-FIRE PERFORMANCE PROFILE
MISSION: DEFEND FROM A BATTLE POSITION (DAY)

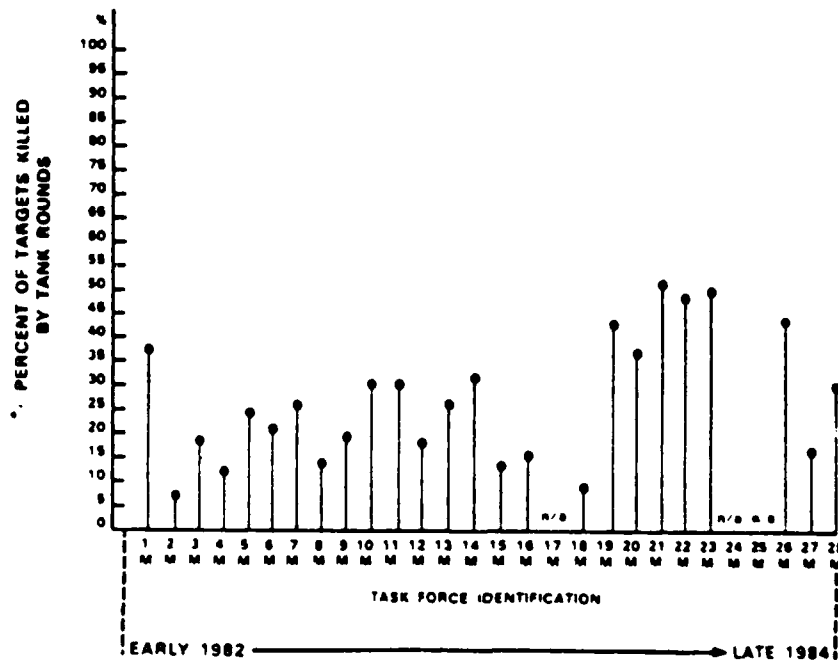
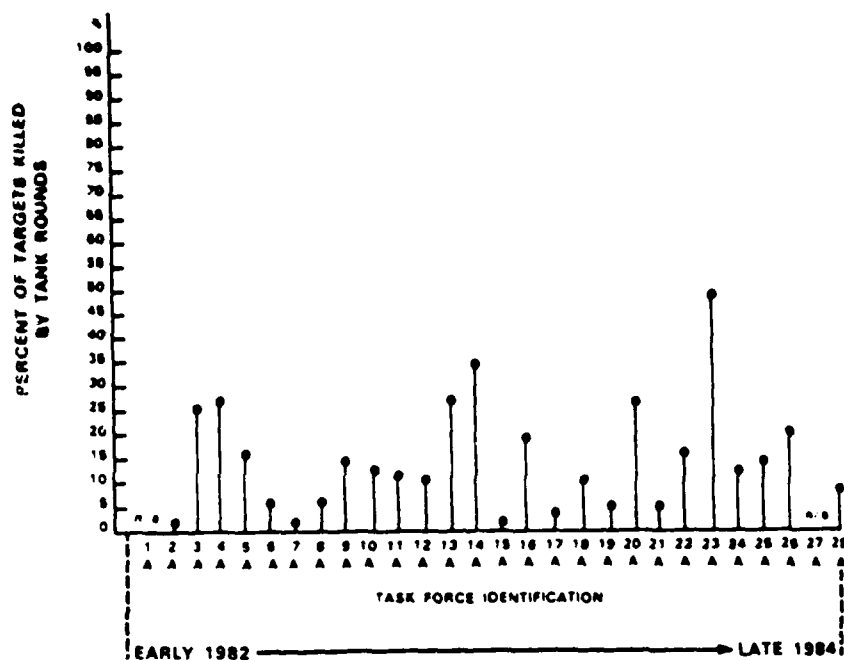


Figure II-2 Performance of all Mechanized Task Force Rotations in the Defense (Day)

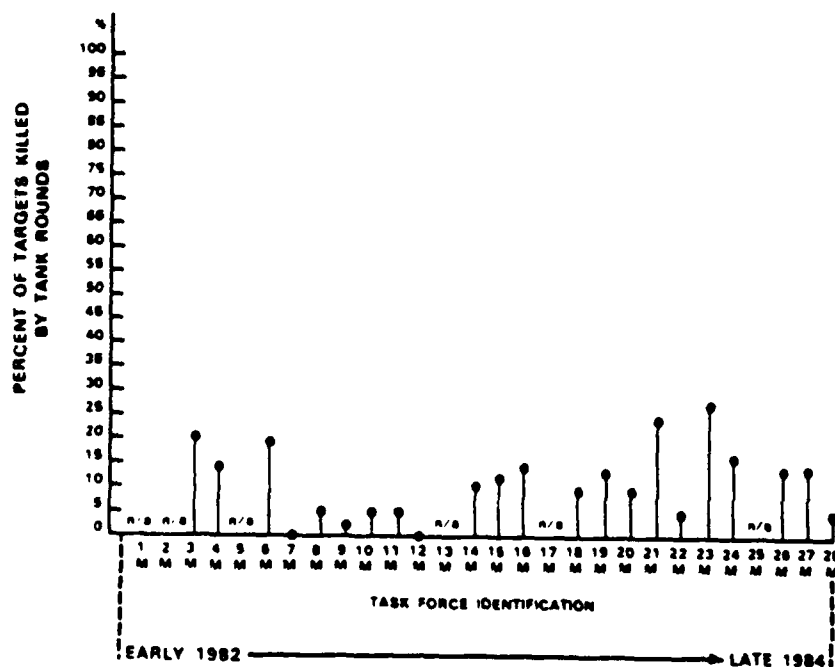
BATTALION TASK FORCE LIVE-FIRE PERFORMANCE PROFILE
MISSION: DEFEND FROM A BATTLE POSITION (NIGHT)



n/a - not available

Figure II-3 Performance of all Armor Task Force Rotations in the Defense (Night)

BATTALION TASK FORCE LIVE-FIRE PERFORMANCE PROFILE
MISSION: DEFEND FROM A BATTLE POSITION (NIGHT)



n/a - not available

Figure II-4 Performance of all Mechanized Task Force Rotations in the Defense (Night)

BATTALION TASK FORCE LIVE-FIRE PERFORMANCE PROFILE
MISSION: MOVEMENT TO CONTACT (DAY)

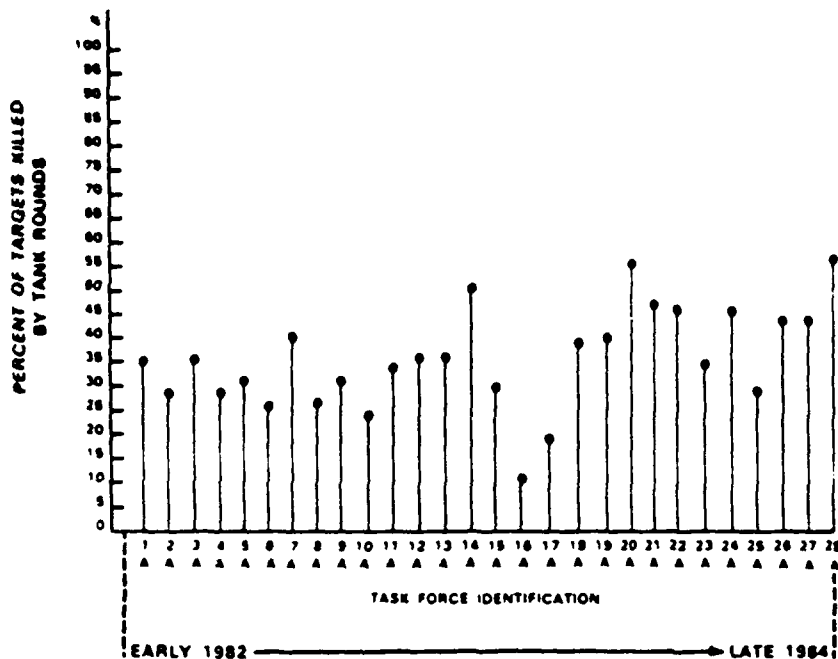
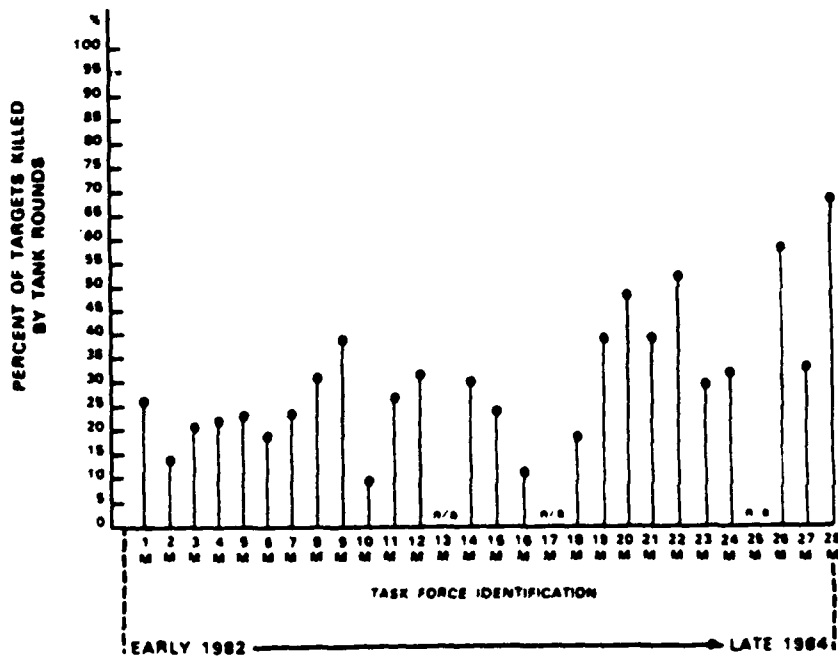


Figure II-5 Performance of all Armor Task Force Rotations in the Offense

BATTALION TASK FORCE LIVE-FIRE PERFORMANCE PROFILE
MISSION: MOVEMENT TO CONTACT (DAY)



N/A NOT AVAILABLE

Figure II-6 Performance of all Mechanized Task Force Rotations in the Offense

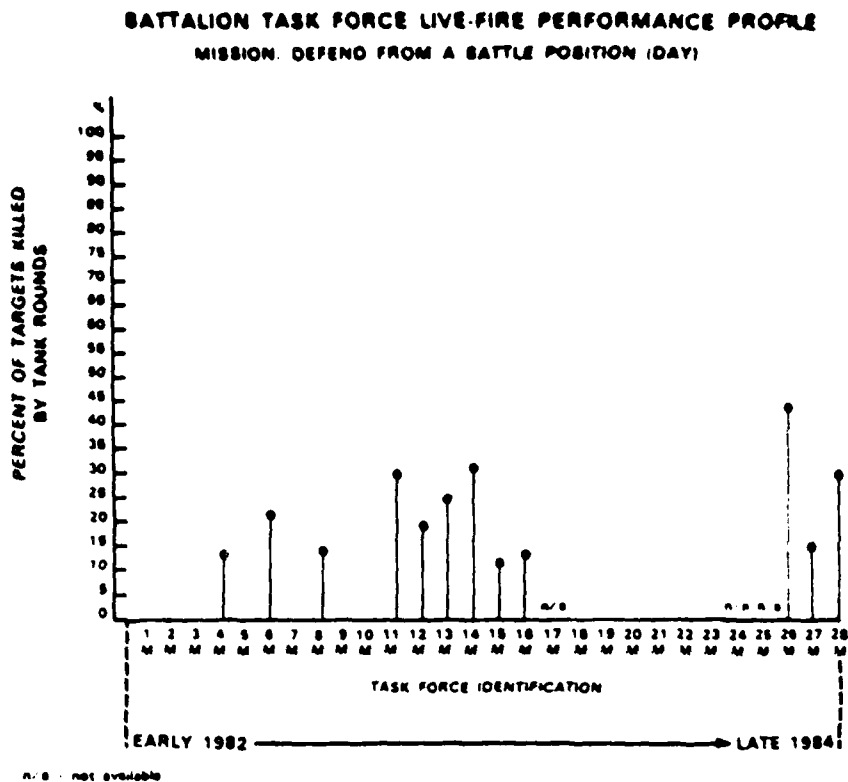


Figure II-7 Performance of One-Time Armor Task Force Rotations in the Defense (Day)

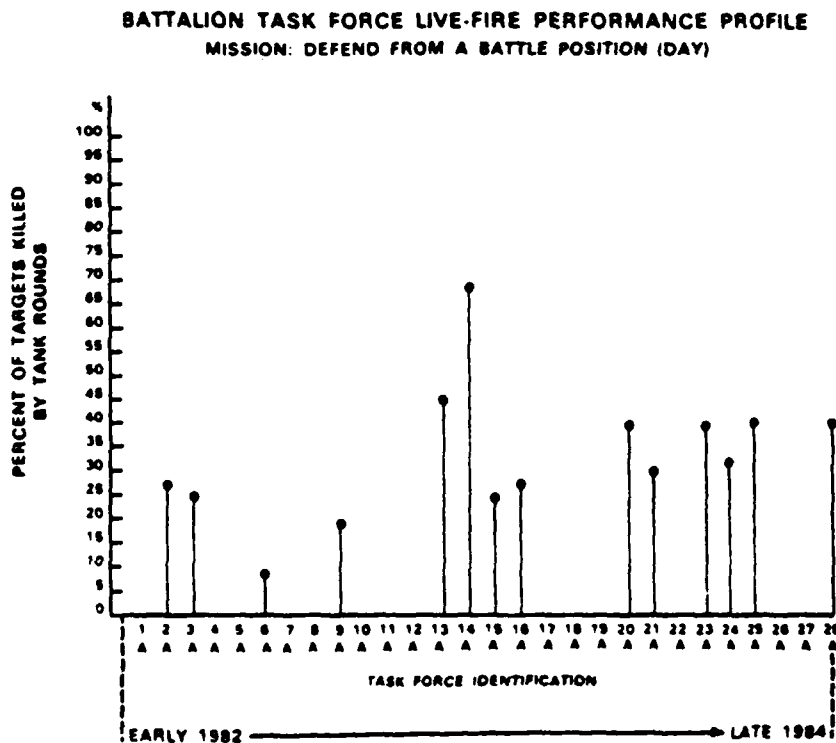


Figure II-8 Performance of One-Time Mechanized Task Force Rotations in the Defense (Day)

BATTALION TASK FORCE LIVE-FIRE PERFORMANCE PROFILE
MISSION: DEFEND FROM A BATTLE POSITION (NIGHT)

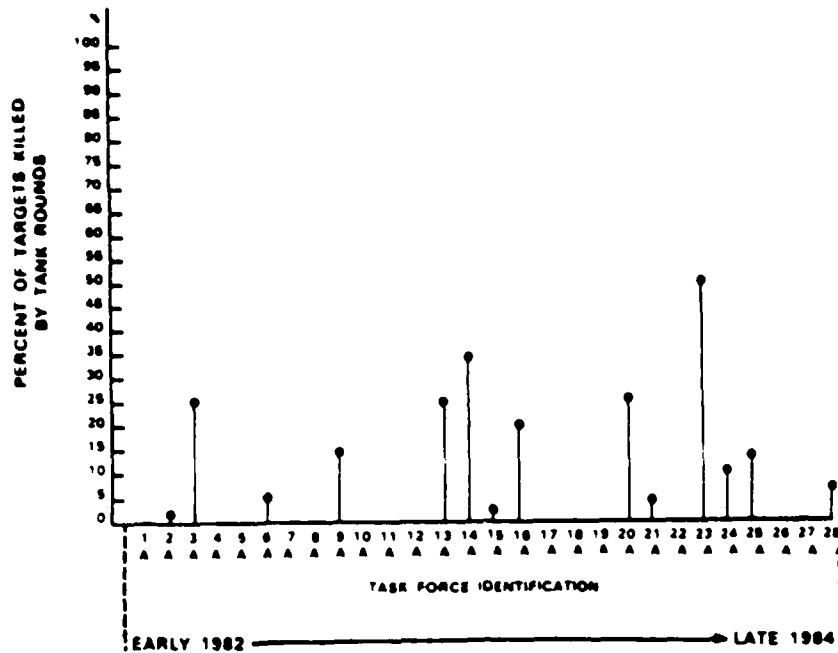


Figure 11-9 Performance of One-Time Armor Task Force Rotations in the Defense (Night)

BATTALION TASK FORCE LIVE-FIRE PERFORMANCE PROFILE
MISSION: DEFEND FROM A BATTLE POSITION (NIGHT)

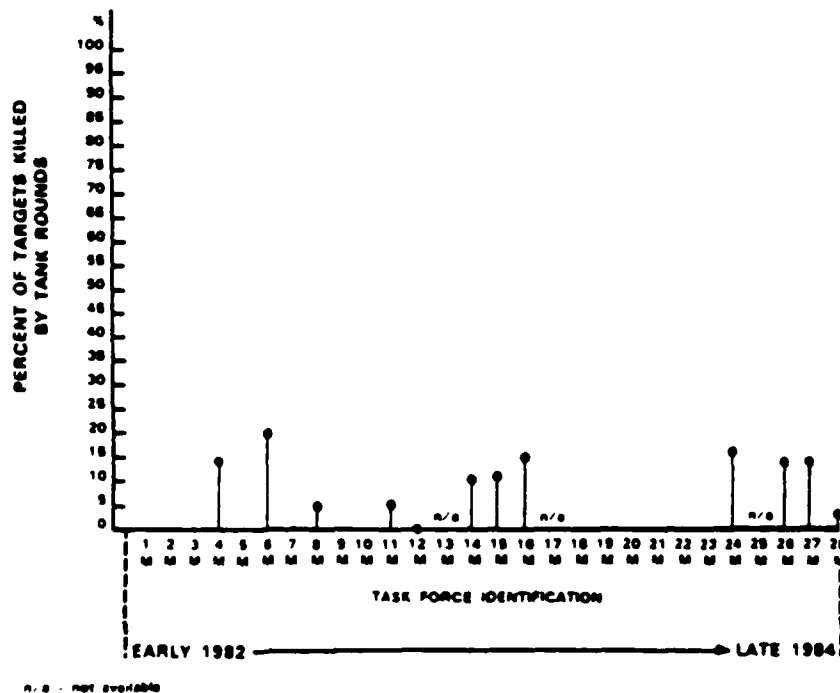


Figure 11-10 Performance of One-Time Mechanized Task Force Rotations in the Defense (Night)

BATTALION TASK FORCE LIVE-FIRE PERFORMANCE PROFILE
MISSION: MOVEMENT TO CONTACT (DAY)

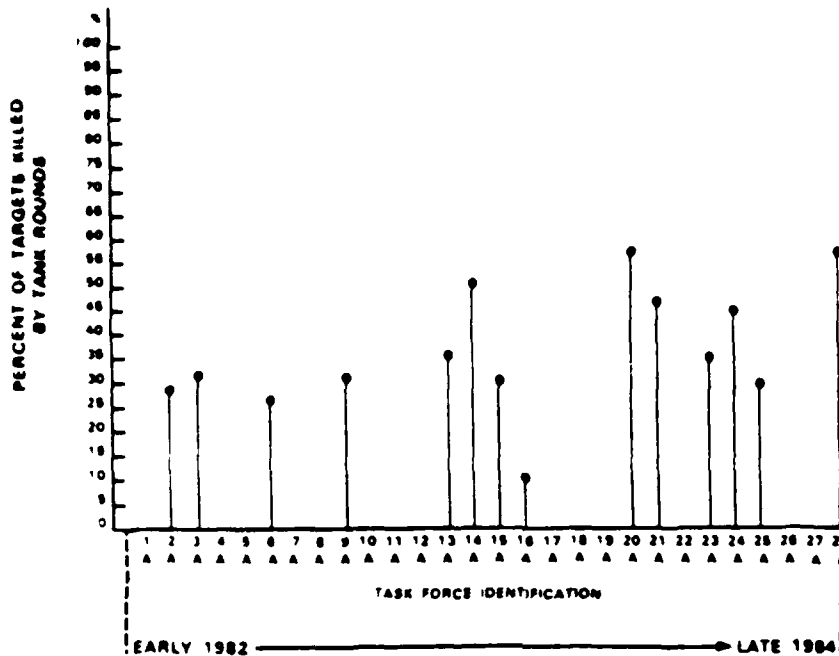


Figure II-11 Performance of One-Time Armor Task Force Rotations in the Offense

BATTALION TASK FORCE LIVE-FIRE PERFORMANCE PROFILE
MISSION: MOVEMENT TO CONTACT (DAY)

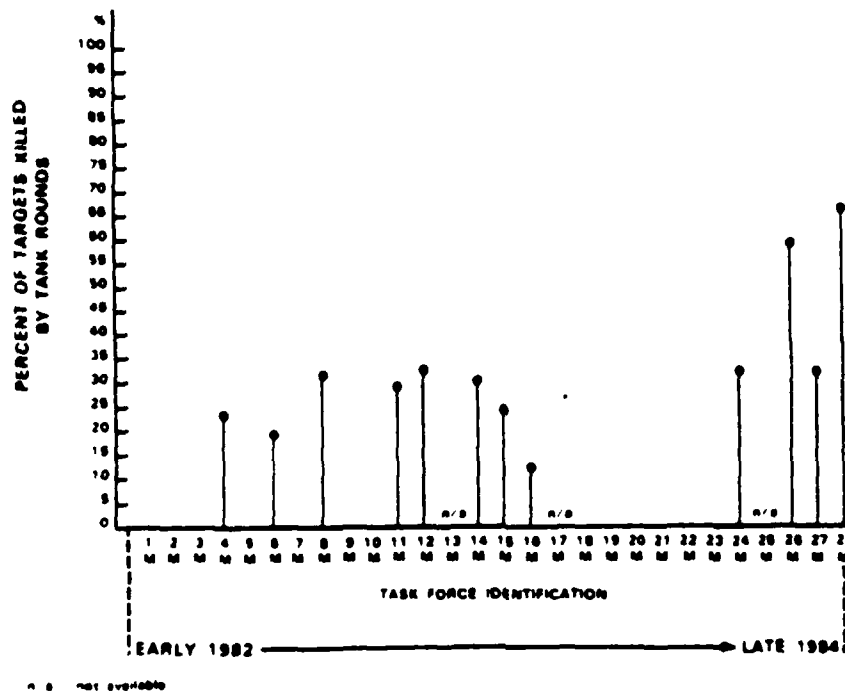


Figure II-12 Performance of One-Time Mechanized Task Force Rotations in the Offense

BATTALION TASK FORCE LIVE-FIRE PERFORMANCE PROFILE
MISSION: DEFEND FROM A BATTLE POSITION (DAY)

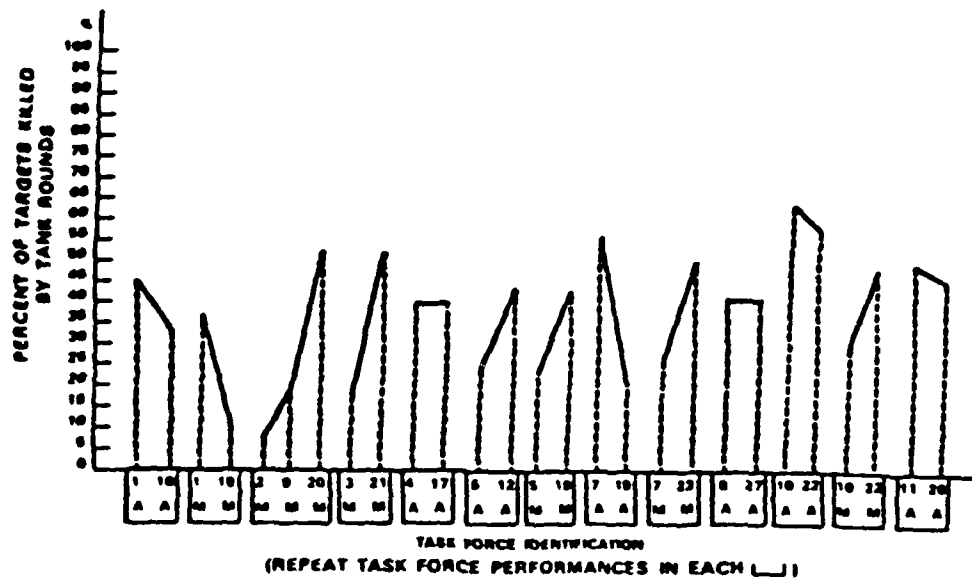


Figure II-13 Performance of all Battalion Task Forces with Repeat Performances in Defense (Day)

BATTALION TASK FORCE LIVE-FIRE PERFORMANCE PROFILE
MISSION: DEFEND FROM A BATTLE POSITION (NIGHT)



n/a - not available

Figure II-14 Performance of all Battalion Task Forces with Repeat Performances in Defense (Night)

BATTALION TASK FORCE LIVE-FIRE PERFORMANCE PROFILE
MISSION: MOVEMENT TO CONTACT (DAY)



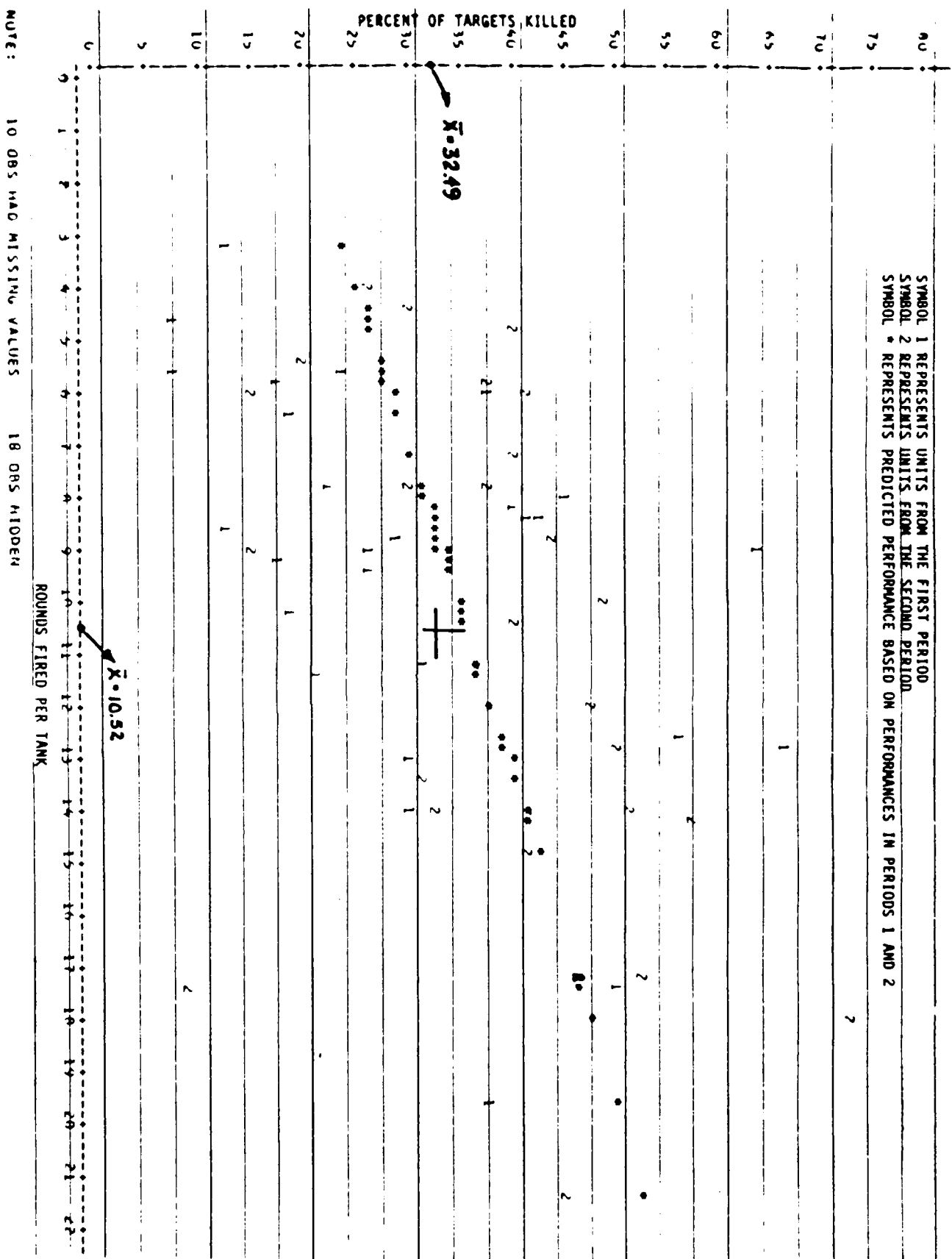
Figure II-15 Performance of all Battalion Task Forces with Repeat Performances in Offense (Day)

APPENDIX III

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REGRESSION ANALYSIS GRAPHS

SYMBOL 1 REPRESENTS UNITS FROM THE FIRST PERIOD
 SYMBOL 2 REPRESENTS UNITS FROM THE SECOND PERIOD
 SYMBOL * REPRESENTS PREDICTED PERFORMANCE BASED ON PERFORMANCES IN PERIODS 1 AND 2



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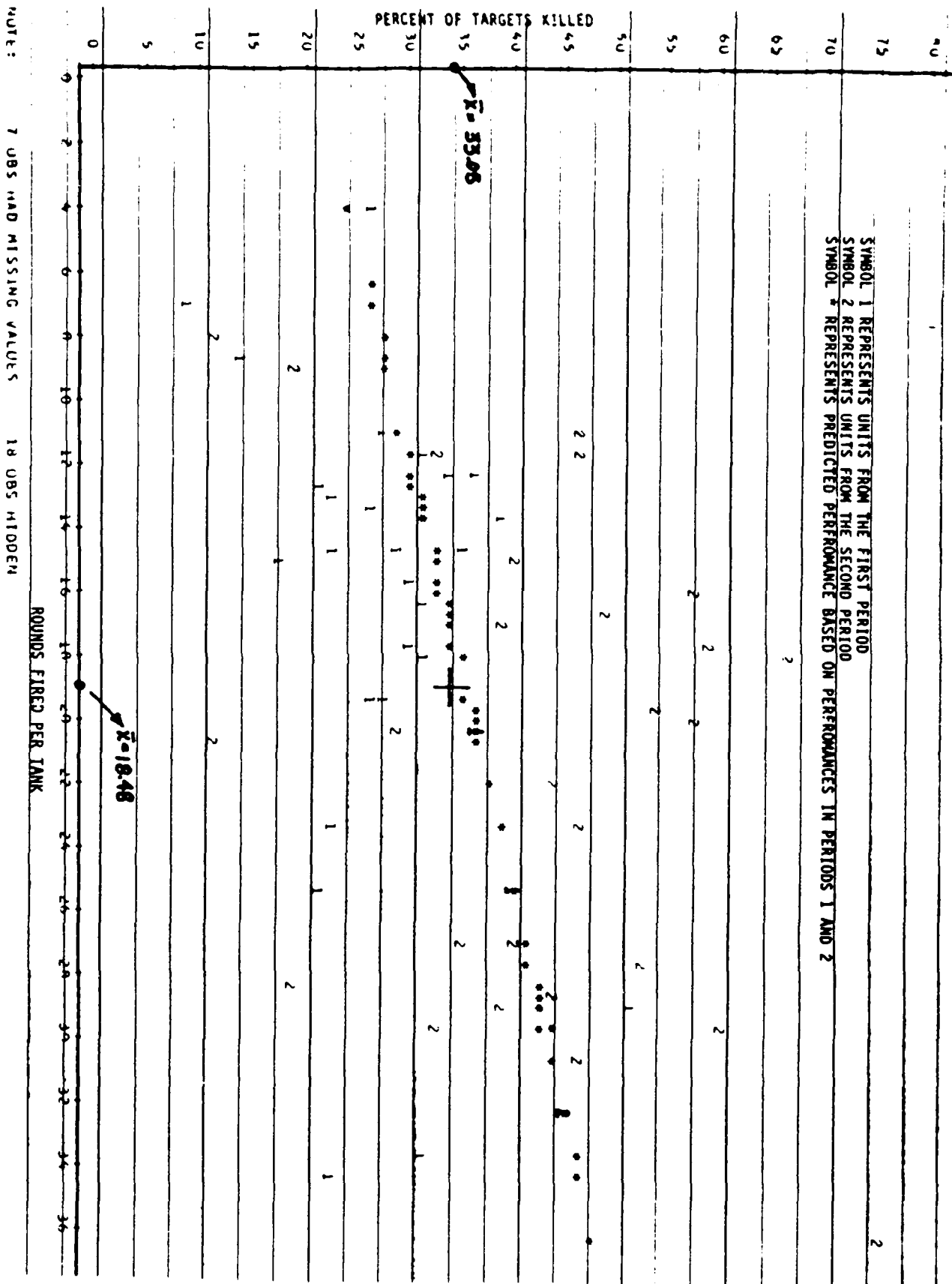
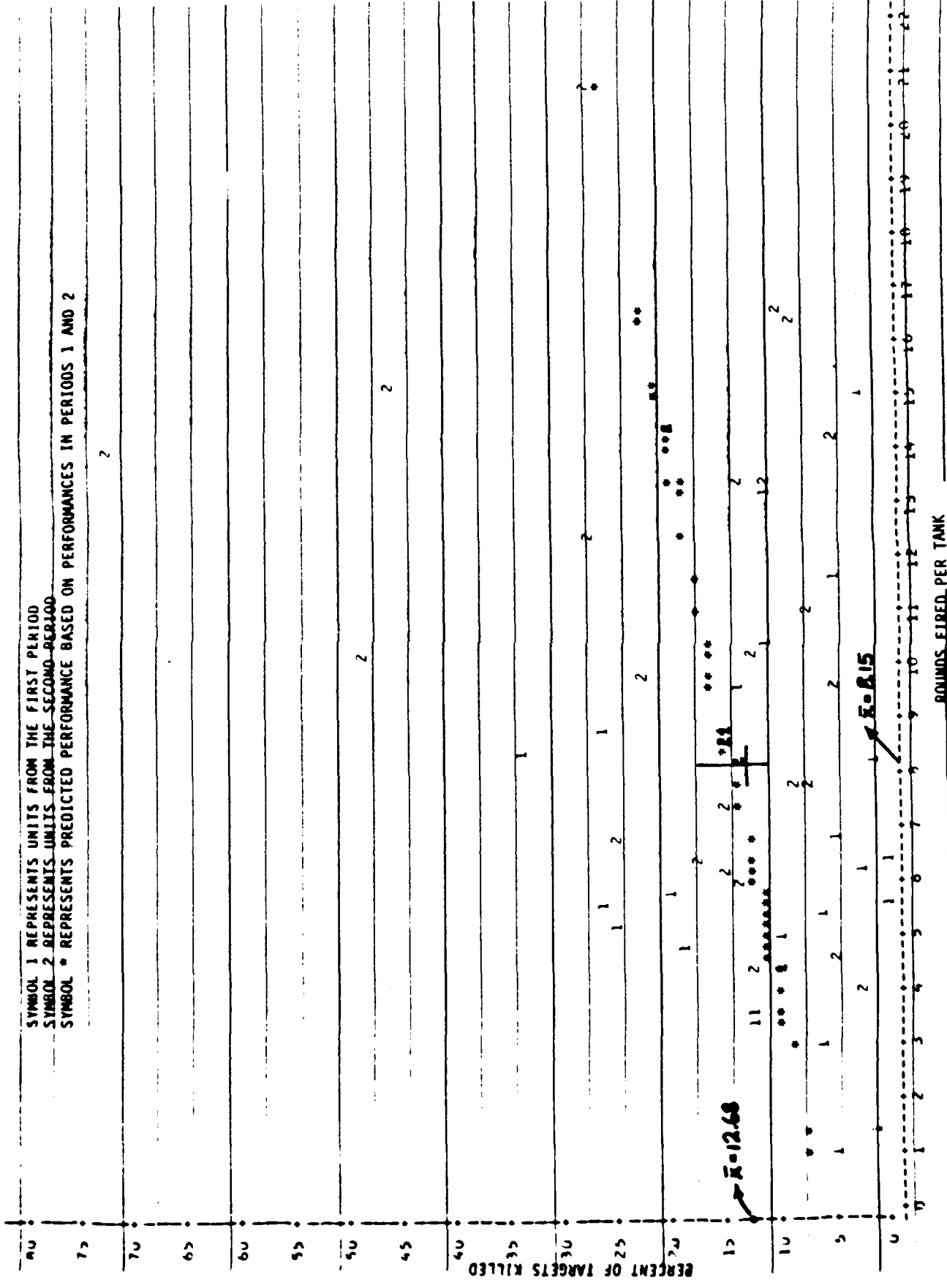


Figure III-2 Rounds Per Tank Vs. Percent Killed for Defensive Mission (Day)

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NOTE: 10 OBS HAD MISSING VALUES 12 OBS HIDDEN

Figure III-3 Rounds Per Tank Vs. Percent Killed for Defensive Mission (Night)